US009064670B2

(12) **United States Patent**
Kim et al.

(10) **Patent No.: US 9,064,670 B2**
(45) **Date of Patent: Jun. 23, 2015**

(54) **ELECTRON EMISSION DEVICE AND X-RAY GENERATOR INCLUDING THE SAME**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 144 days.

(21) Appl. No.: **13/771,736**

(22) Filed: **Feb. 20, 2013**

(65) **Prior Publication Data**

US 2013/0230146 A1 Sep. 5, 2013

(30) **Foreign Application Priority Data**

Mar. 2, 2012 (KR) 10-2012-0022033

(51) **Int. Cl.**

H01J 35/06	(2006.01)
H05G 1/52	(2006.01)
H01J 29/02	(2006.01)
H01J 35/04	(2006.01)
H01J 3/02	(2006.01)

(52) **U.S. Cl.**

CPC ***H01J 29/025*** (2013.01); ***H01J 35/045*** (2013.01); ***H01J 3/021*** (2013.01); *H01J 2203/0216* (2013.01); *H01J 2203/0236* (2013.01); *H01J 2203/0244* (2013.01); *H01J 2203/0272* (2013.01); ***H01J 35/065*** (2013.01); *H01J 2235/068* (2013.01)

(58) **Field of Classification Search**

CPC H01J 35/065; H01J 35/14; H01J 35/06; H01J 35/04; H05G 1/52; H05G 1/02

USPC .... 378/91, 113, 119, 122, 134, 136, 138, 378/210; 250/396 R, 397, 423 R, 423 F, 250/493.1, 494.1, 503.1, 526; 313/399, 313/409, 414–417, 441, 446, 447, 452, 456, 313/457, 238, 243, 244, 252, 268, 292–302, 313/304, 310

See application file for complete search history.

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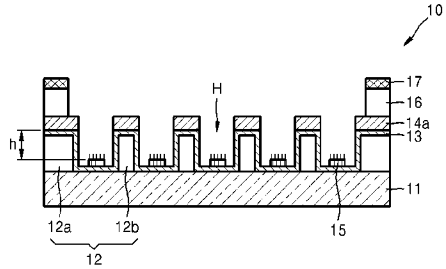
(57) **ABSTRACT**

An electron emission device includes a cathode electrode; a mesh-shaped gate electrode spaced apart from the cathode electrode; a plurality of gate spacers between the cathode electrode and the gate electrode; and a plurality of electron emission sources between the cathode electrode and the gate electrode, and alternating with the plurality of gate spacers.

17 Claims, 5 Drawing Sheets



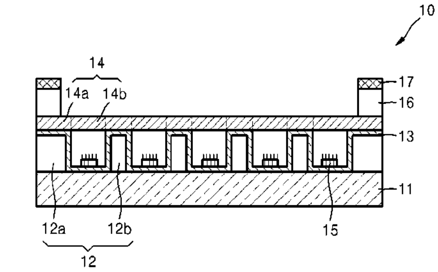


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FIG. 1

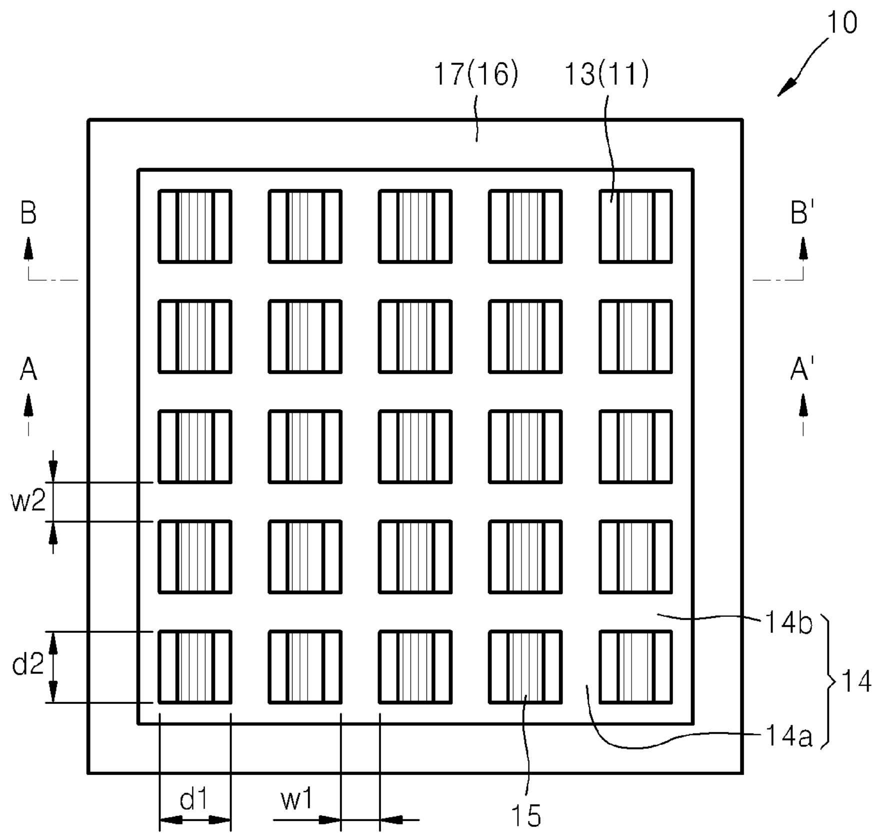

10
17(16)
13(11)
B
B'
A
A'
w2
d2
14b
14
14a
d1
w1
15

FIG. 2A

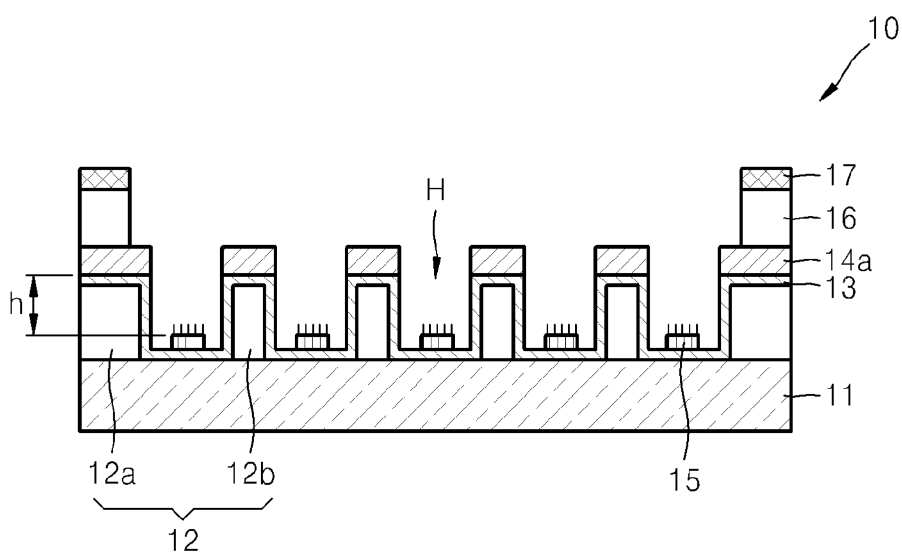
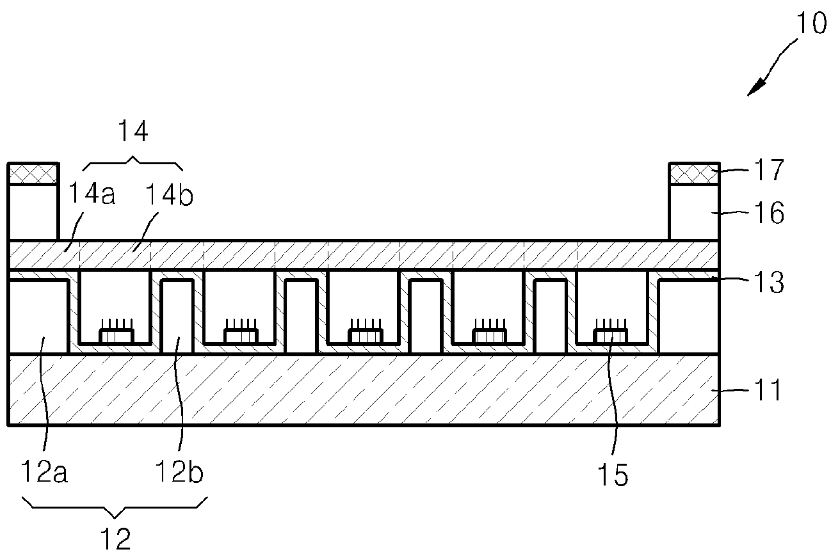
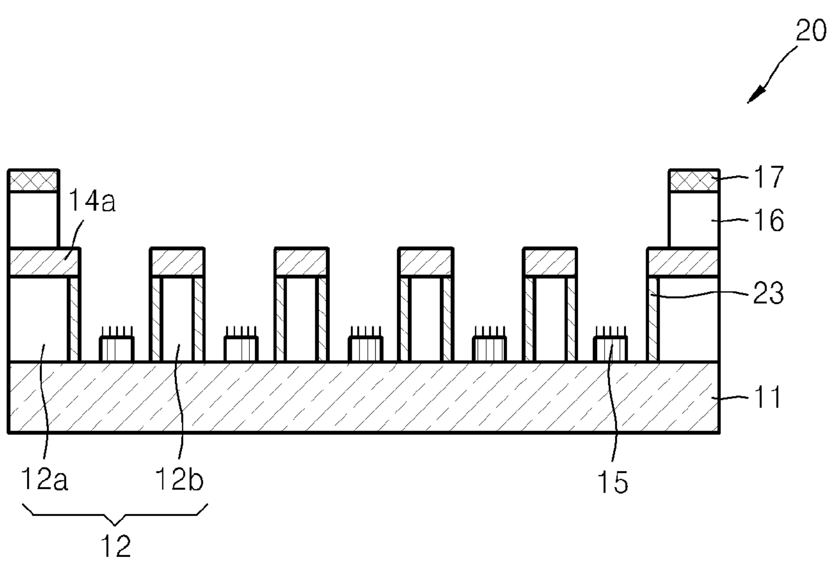

10
H
17
16
14a
13
h
11
12a
12b
15
12

FIG. 2B



10
14
14a
14b
17
16
13
11
12a
12b
15
12

FIG. 3



20
14a
17
16
23
11
12a
12b
15
12

FIG. 4

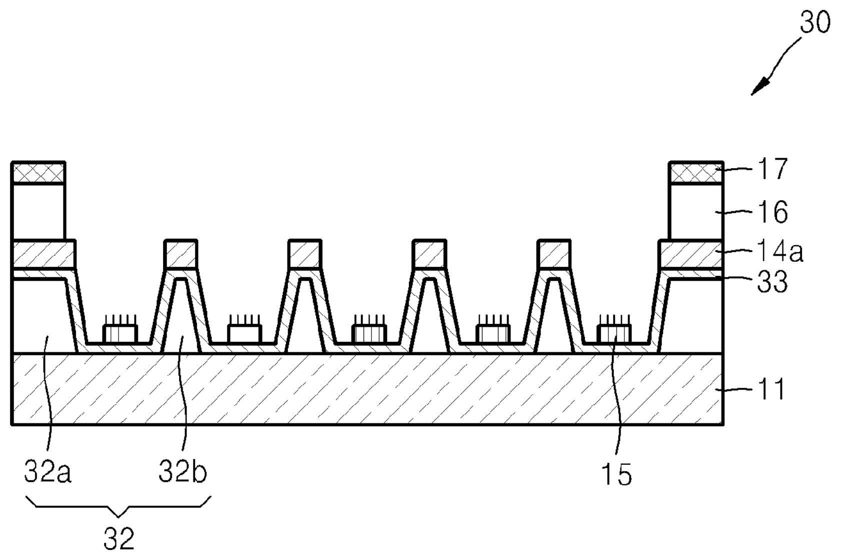

30
17
16
14a
33
11
32a
32b
15
32

FIG. 5

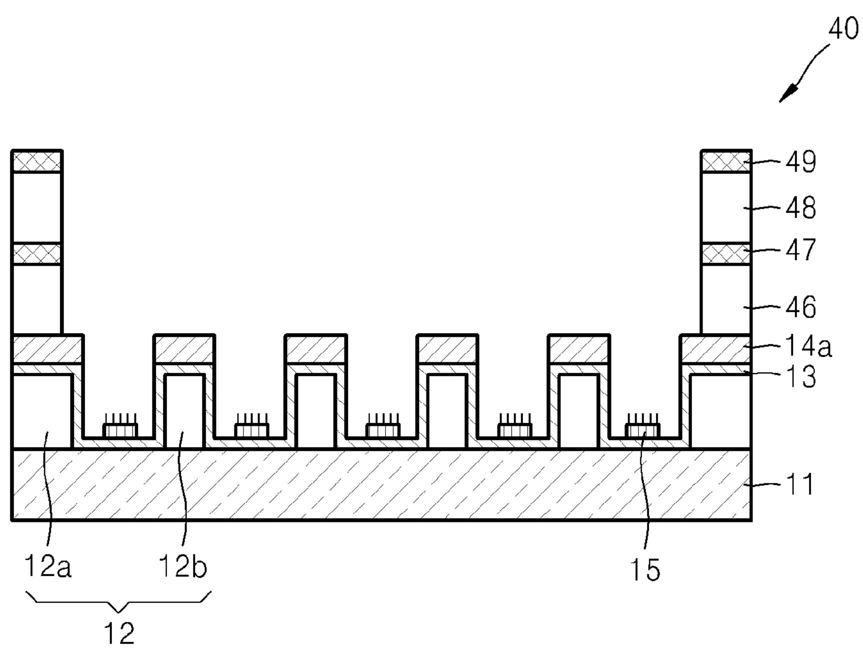

40
49
48
47
46
14a
13
11
12a
12b
15
12

FIG. 6

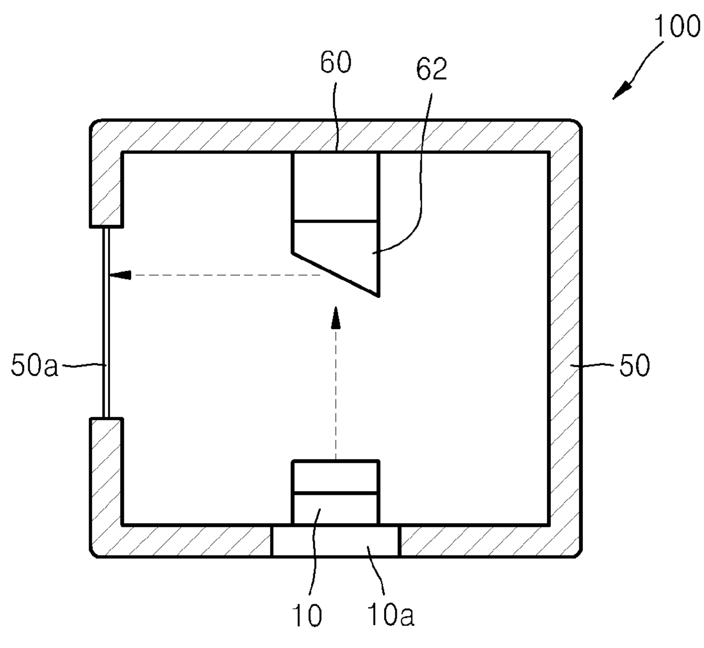
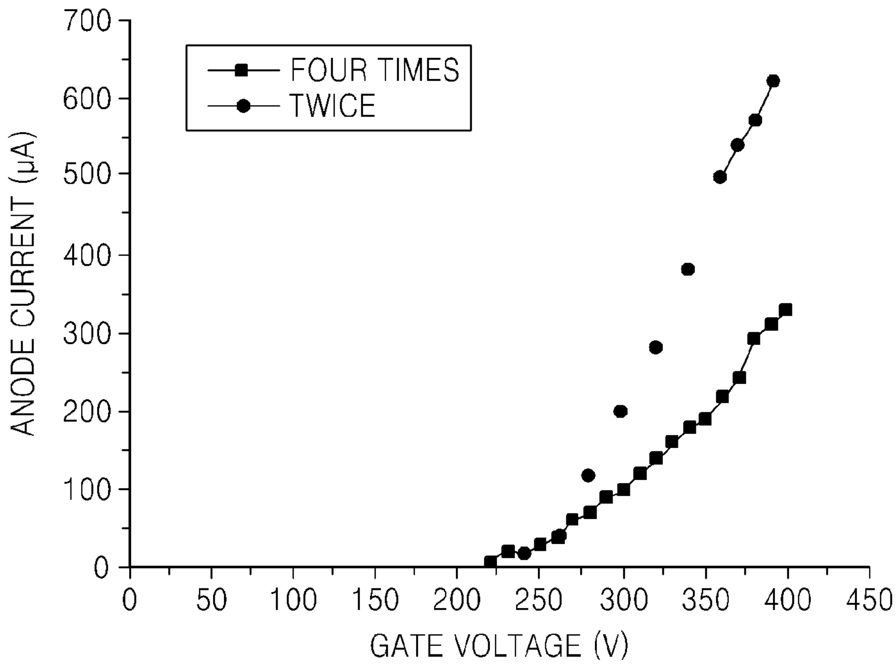


FIG. 7


FOUR TIMES
TWICE
ANODE CURRENT (μA)
GATE VOLTAGE (V)
0
100
200
300
400
500
600
700
0
50
100
150
200
250
300
350
400
450

ELECTRON EMISSION DEVICE AND X-RAY GENERATOR INCLUDING THE SAME

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority to Korean Patent Application No. 10-2012-0022033, filed on Mar. 2, 2012, and all the benefits accruing therefrom under 35 U.S.C. §119, the disclosure of which is incorporated herein in its entirety by reference.

BACKGROUND

1. Field

Provided is an electron emission device using electric field emission and an X-ray generator including the same.

2. Description of the Related Art

X-rays are used in non-destructive testing, structural and physical properties testing, image diagnosis, security inspection and the like in the fields of industry, science, medical treatment, etc. Generally, a photographing apparatus using X-rays for such purposes includes an X-ray generator for radiating an X-ray and a detector for detecting an X-ray that s passed through an object.

Generally, the X-ray generator radiates an X-ray by colliding electrons emitted from a cathode, with an anode. An electron emission device that is used in the X-ray generator may be divided into a cold cathode and a hot cathode. An electron emission device using electric field emission may also be easily driven at a low voltage. Thus, much research is being conducted in order to commercialize the electron emission device using electric field emission.

SUMMARY

Provided is an electron emission device for preventing arcing by preventing an insulation material from being charged with electric charges.

Provided is an electron emission device in which a uniform electric field may be formed.

Additional aspects will be set forth in part in the description which follows and, in part, will be apparent from the description, or may be learned by practice of the presented embodiments.

According to an aspect of the present invention, an electron emission device includes: a cathode electrode; a mesh-shaped gate electrode spaced apart from the cathode electrode; a plurality of gate spacers between the cathode electrode and the gate electrode; and a plurality of electron emission sources between the cathode electrode and the gate electrode and alternating with the plurality of gate spacers.

A plurality of openings may be defined in the gate electrode and expose a portion of each electron emission source which is between adjacent gate spacers.

The mesh-shaped gate electrode may include: a plurality of gate lines respectively on the plurality of gate spacers; and a plurality of gate bridges which connect the plurality of gate lines to each other.

An interval between two adjacent gate bridges from among the plurality of gate bridges may be equal to or larger than a width of a gate bridge.

An interval between two adjacent gate bridges from among the plurality of gate bridges may be equal to or less than twice a distance between the electron emission sources and the gate electrode.

The plurality of gate spacers or the plurality of electron emission sources may be linear-shaped.

The electron emission device may further include a charging prevention film on the plurality of gate spacers. The charging prevention film prevents electrical charging of the plurality of gate spacers by electrons emitted by the plurality of electron emission sources.

The charging prevention film may be on lateral sides of the plurality of gate spacers and may be connected to the gate electrode.

The charging prevention film may be further on an upper side of each of the plurality of gate spacers. The charging prevention film may be further on an upper side of the cathode electrode.

A resistivity of the charging prevention film may be between a resistivity of the gate electrode and a resistivity of the plurality of gate spacers.

A resistivity of the charging prevention film may be in a range from about 10^7 ohms centimeter (Ω cm) to about $10^{10}\Omega$ cm.

A cross-sectional width of each of the plurality of gate spacers may decrease in a direction from the cathode electrode to the gate electrode.

The electron emission device may further include: a focusing gate spaced apart from the gate electrode and focusing electrons emitted from the plurality of electron emission sources; and a focusing spacer between the gate electrode and the focusing gate.

The electron emission device may include a plurality of focusing gates including first and second focusing gates sequentially disposed spaced apart from the gate electrode, and a plurality of focusing spacers including first and second focusing spacers, where the first focusing gate is between the first and second focusing spacers.

A positive voltage may be applied to the first focusing gate and a negative voltage may be applied to the second focusing gate.

The cathode electrode, the plurality of gate spacers and the plurality of electron emission sources may be integrated, and the gate electrode may be detachable from and attachable to the plurality of gate spacers.

According to another aspect of the present invention, an X-ray generator includes: a container unit; the electron emission device as describe above in the container unit; and an anode which generates X-rays by using electrons emitted from the electron emission device.

The electron emission device may be detachable from and attachable to the container unit.

BRIEF DESCRIPTION OF THE DRAWINGS

These and/or other aspects will become apparent and more readily appreciated from the following description of the embodiments, taken in conjunction with the accompanying drawings in which:

FIG. **1** is a plan view illustrating an embodiment of an electron emission device according to the present invention;

FIG. **2**A is a cross-sectional view taken along line A-A' illustrated in FIG. **1**;

FIG. **2**B is a cross-sectional view taken along line B-B' illustrated in FIG. **1**;

FIG. **3** is a cross-sectional view illustrating another embodiment of an electron emission device according to the present invention;

FIG. **4** is a cross-sectional view illustrating another embodiment of an electron emission device according to the present invention;

FIG. **5** is a cross-sectional view illustrating another embodiment of an electron emission device according to the present invention;

FIG. **6** is a diagram illustrating an embodiment of an X-ray generator including an electron emission device, according to the present invention; and

FIG. **7** is a diagram illustrating results of an experiment regarding a relationship between an interval between gate bridges and a current in microamps (μA) flowing through an anode, depending on a gate voltage in volts (V), according to the present invention.

DETAILED DESCRIPTION

Reference will now be made in detail to embodiments, examples of which are illustrated in the accompanying drawings, wherein like reference numerals refer to like elements throughout. In this regard, the present embodiments may have different forms and should not be construed as being limited to the descriptions set forth herein. Accordingly, the embodiments are merely described below, by referring to the figures, to explain aspects of the present description. Expressions such as "at least one of," when preceding a list of elements, modify the entire list of elements and do not modify the individual elements of the list.

It will be understood that when an element or layer is referred to as being "on" or "connected to" another element or layer, the element or layer can be directly on or connected to another element or layer or intervening elements or layers. In contrast, when an element is referred to as being "directly on" or "directly connected to" another element or layer, there are no intervening elements or layers present. As used herein, connected may refer to elements being physically and/or electrically connected to each other. Like numbers refer to like elements throughout. As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items.

It will be understood that, although the terms first, second, third, etc., may be used herein to describe various elements, components, regions, layers and/or sections, these elements, components, regions, layers and/or sections should not be limited by these terms. These terms are only used to distinguish one element, component, region, layer or section from another region, layer or section. Thus, a first element, component, region, layer or section discussed below could be termed a second element, component, region, layer or section without departing from the teachings of the invention.

Spatially relative terms, such as "lower," "under," "above," "upper" and the like, may be used herein for ease of description to describe the relationship of one element or feature to another element(s) or feature(s) as illustrated in the figures. It will be understood that the spatially relative terms are intended to encompass different orientations of the device in use or operation, in addition to the orientation depicted in the figures. For example, if the device in the figures is turned over, elements described as "under" relative to other elements or features would then be oriented "above" relative to the other elements or features. Thus, the exemplary term "under" can encompass both an orientation of above and below. The device may be otherwise oriented (rotated 90 degrees or at other orientations) and the spatially relative descriptors used herein interpreted accordingly.

The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the invention. As used herein, the singular forms "a," "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises," "comprising," "includes" and/or "including," when used in this specification, specify the presence of stated features, integers, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof.

Embodiments of the invention are described herein with reference to cross-section illustrations that are schematic illustrations of idealized embodiments (and intermediate structures) of the invention. As such, variations from the shapes of the illustrations as a result, for example, of manufacturing techniques and/or tolerances, are to be expected. Thus, embodiments of the invention should not be construed as limited to the particular shapes of regions illustrated herein but are to include deviations in shapes that result, for example, from manufacturing.

Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. It will be further understood that terms, such as those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of the relevant art and will not be interpreted in an idealized or overly formal sense unless expressly so defined herein.

Hereinafter, the invention will be described in detail with reference to the accompanying drawings.

FIG. **1** is a plan view illustrating an embodiment of an electron emission device **10** according to the present invention, FIG. **2**A is a cross-sectional view taken along line A-A' illustrated in FIG. **1**, and FIG. **2**B is a cross-sectional view taken along line B-B' illustrated in FIG. **1**.

Referring to FIGS. **1**, **2**A, and **2**B, the electron emission device **10** includes a cathode electrode **11**, a gate electrode **14** that is disposed spaced apart from the cathode electrode **11** in a cross-sectional direction and has a mesh structure in a plan view, a plurality of gate spacers **12** that extend in a first direction between the cathode electrode **11** and the gate electrode **14** and are disposed spaced apart from each other in a second direction different from the first direction, and a plurality of electron emission sources **15**. The first direction may be an up-down direction in FIG. **1** while the second direction may be a left-right direction in FIG. **1**.

The cathode electrode **11** and the gate electrode **14** may include a conductive material, such as a metal, a conductive metal oxide, or the like. In one embodiment, for example, the cathode electrode **11** and the gate electrode **14** may include a metal such as Ti, Pt, Ru, Au, Ag, Mo, Al, W, or Cu, or may include a metal oxide such as indium tin oxide ("ITO"), aluminum zinc oxide ("AZO"), indium zinc oxide ("IZO"), tin oxide (SnO_2) or In_2O_3.

The cathode electrode **11** applies a voltage to the electron emission sources **15**, and may have a substantially planar shape. The gate electrode **14** receives a voltage having a different level from a voltage that is applied to the cathode electrode **11**, and induces electron emission of the electron emission sources **15**.

The gate electrode **14** may have a mesh structure in the plan view, and a plurality of openings H may be defined in the gate electrode **14**. In one embodiment, or example, the gate electrode **14** may include a plurality of gate lines **14*a*** on and overlapping the gate spacers **12**. The gate lines **14*a*** have a longitudinal axis which extends in the first direction, and are spaced apart from each other in the second direction. The gate electrode **14** may further include a plurality of gate bridges **14*b*** that connect the plurality of gate lines **14*a*** to each other.

The plurality of gate bridges **14***b* has a longitudinal axis which extends in the second direction, and the gate bridges **14***b* are spaced apart from each other in the first direction. Thus, the openings H may be defined by using two adjacent gate lines **14***a* and two adjacent gate bridges **14***b*. The openings H may be disposed so that at least a portion of each of the electron emission sources **15** is exposed between the gate spacers **12**.

The width w_1 of the gate lines **14***a* may be equal to or different from the width w_2 of the gate bridges **14***b*. In addition, an interval d_1 between the gate lines **14***a* may be equal to or different from an interval d_2 between the gate bridges **14***b*. In one exemplary embodiment, for example, the interval d_2 between the gate bridges **14***b* may be equal to or larger than the width w_2 of the gate bridges **14***b*, and the interval d_2 between the gate bridges **14***b* may be equal to or less than twice a distance h between the electron emission sources **15** and the gate electrode **14**. If the interval d_2 between the gate bridges **14***b* is more than twice the distance h between the electron emission sources **15** and the gate electrode **14**, non-uniformity of an electric field that is formed in the electron emission sources **15** increases. That is, a larger electric field is formed under the gate bridges **14***b*, and thus, electron emission from the electron emission sources **15** becomes non-uniform.

The electron emission device **10** having a relatively large planar area may be manufactured since the gate electrode **14** has the mesh structure as stated above. Although, in FIG. **1**, the planar shape of the openings H of the gate electrode **14** is a quadrangle, the present invention is not limited thereto. The shape of the openings H may be at least one from among a circle, an oval and a polygon. The planar sizes or dimensions of the openings H may be equal to each other, or alternatively, may be different from each other.

The gate spacers **12** are disposed between the cathode electrode **11** and the gate electrode **14** and reduce or effectively prevent an electrical current from flowing between the cathode electrode **11** and the gate electrode **14**. In addition, the number of gate spacers **12** may be more than three. The gate spacers **12** may have a substantially linear shape in the plan view. Thus, the gate spacers **12** extend in a predetermined direction and are disposed spaced apart from each other in another predetermined direction to support the gate electrode **14** thereon. In one embodiment, the gate spacers **12** have a longitudinal axis which extends in the first direction and are spaced apart from each other in the second direction. The gate spacers **12** may include a first gate spacer **12***a* for supporting an edge area of the gate electrode **14** and a second gate spacer **12***b* for supporting a non-edge area of the gate electrode **14** between the edge areas and at a center.

An interval between the gate spacers **12** in the second direction may be equal to or larger than an interval between the gate lines **14***a* in the same second direction. The gate spacers **12** may include an insulation material that is used in a semiconductor device, e.g., the electron emission device **10**. In one embodiment, for example, the gate spacers **12** may include SiO_2, or may include HfO_2, Al_2O_3, Si_3N_4, or a compound thereof, which are high-K materials having high permittivity compared to SiO_2.

Although, the gate spacers **12** having a linear shape are illustrated in FIGS. **2**A and **2**B, the present invention is not limited thereto. The gate spacers **12** may have a different planar shape so long as such different shape reduces or effectively prevents an electrical current from flowing between the cathode electrode **11** and the gate electrode **14** and supports the gate electrode **14**. In one embodiment, for example, the second gate spacer **12***b* may have a pillar shape that is disposed under the gate line **14***a*, but is not limited thereto or thereby. As the pillar shape, a cross-sectional width may be substantially constant in a direction from the cathode electrode **11** to the gate electrode **14**.

The electron emission sources **15** emit electrons due to a voltage that is applied to the cathode electrode **11** and the gate electrode **14**. The electron emission device **10** may include the plurality of electron emission sources **15** as stated above, and the plurality of electron emission sources **15** may be alternately disposed with the plurality of gate spacers **12**. In one embodiment, for example, the plurality of electron emission sources **15** may be disposed spaced apart from each other while placing the second gate spacer **12***b* between them. The electron emission sources **15** may have a stripe shape extending in the first direction like the second gate spacer **12***b*. That is, the electron emission sources **15** may be elongated in the first direction, and be spaced apart from each other in the second direction. While the electron emission sources **15** are exposed by the holes H, they are overlapped by the gate bridges **14***b*. Since the gate electrode **14** has the mesh structure, the gate electrode **14** is disposed also over the electron emission sources **15**. Thus, the electron emission sources **15** may be disposed spaced apart from the gate electrode **14** in the cross-sectional direction so that the electron emission sources **15** and the gate electrode **14** are not electrically shorted.

The electron emission sources **15** may include a material that may emit electrons. In one embodiment, for example, the electron emission sources **15** may include metal, silicon, oxide, diamond, diamond like carbon ("DLC"), carbide compound, nitride, carbon nanotube, carbon nanofiber or the like.

In one embodiment, the cathode electrode **11**, the plurality of gate spacers **12** and the plurality of electron emission sources **15** are integrated, such as non-removable or non-detachable with respect to each other after being attached to each other, and the gate electrode is detachable from and attachable to the plurality of gate spacers **12**. However, the present invention is not limited thereto or thereby.

The electron emission device **10** may emit more electrons as the area of the electron emission sources **15** is larger in the electron emission device **10**. However, the electron emission device **10** has to endure an electrostatic force due to a voltage difference that is applied between the electron emission sources **15** and the gate electrode **14**. Thus, by alternately disposing the gate spacers **12** and the electron emission sources **15**, and by disposing the gate electrode **14** with the openings H defined therein over areas where the electron emission sources **15** are disposed, the electron emission device **10** having the relatively large planar area may be implemented. In addition, since the gate electrode **14** includes the gate bridges **14***b* that are disposed in a direction intersecting with a length direction of the electron emission sources **15**, a uniform electric field may be formed on the surface of the electron emission sources **15**.

In addition, since the electron emission sources **15** are disposed also under and overlapping the gate bridges **14***b*, it is necessary to minimize electrons that are emitted under the gate bridges **14***b*. Thus, the interval d_2 between the gate bridges **14***b* may be larger than the width w_2 of the gate bridges **14***b*. The interval d_2 between the gate bridges **14***b* may be equal to or less than twice the distance h between the electron emission sources **15** and the gate electrode **14**.

The electron emission device **10** may further include a focusing gate **17** which is disposed spaced apart from the gate electrode **14** in the cross-sectional direction and focuses electrons, and a focusing spacer **16** that is disposed between the gate electrode **14** and the focusing gate **17** and prevents an electrical short circuit between the gate electrode **14** and the focusing gate **17**. The focusing gate **17** and the focusing spacer **16** may have a planar shape of a ring or frame whose center area is empty as not including any material of the focusing gate **17** and focusing spacer **16**. An opening at the center area may be considered defined in the focusing gate **17** and the focusing spacer **16**. Thus, electrons passing through the center area of the focusing gate **17** are focused. A voltage that is applied to the focusing gate **17** is equal to or similar to a voltage that is applied to the gate electrode **14**, and thus, an optimum focusing performance may be maintained.

If a voltage is applied between the cathode electrode **11** and the gate electrode **14**, electrons are emitted from the electron emission sources **15** due to a potential difference. The emitted electrons may be discharged to the outside of the electron emission device **10** through the openings H of the gate electrode **14**, but may collide with the gate spacers **12**. In addition, some of electrons proceeding to the gate electrode **14** that do not collide with the gate spacers **12** after the emission of electrons may collide with the gate electrode **14** and then proceed to the gate spacers **12** again. Electrons colliding with the gate spacers **12** accumulate charges on the surface of the gate spacers **12**, and a discharge may occur if charges accumulate over a predetermined level. The electron emission from the gate spacers **12** may generate arcing and thus deteriorate the performance of the electron emission device **10**.

Thus, the electron emission device **10** may further include a charging prevention film **13** that is disposed on the gate spacers **12** and reduces or effectively prevents the gate spacers **12** from being electrically charged by electrons generated in the electron emission sources **15**. The charging prevention film **13** may be disposed to cover the gate spacers **12**, such as to overlap both side and upper surfaces of the gate spacers **12**. The charging prevention film **13** may also be disposed on a portion of the cathode electrode **11** which is exposed between the gate spacers **12**, as well as on the gate spacers **12** themselves. The charging prevention film **13** may be a single, unitary, indivisible member, but is not limited thereto or thereby. The electron emission sources **15** may be disposed on the charging prevention film **13** which overlaps the exposed portion of the cathode electrode **11**. A thickness of the charging prevention film **13** may be less than about 500 angstroms (Å), where the thickness is taken in a direction normal to the respective surface which it covers.

The charging prevention film **13** may include a material having a resistivity value between the resistivity of the gate spacers **12** and the resistivity of the gate electrode **14**. The resistivity value "ρ" may be determined depending on the thickness "t" of the charging prevention film **13**, and the amount "I" of leakage current between the cathode electrode **11** and the gate electrode **14**, which is permitted by the electron emission device **10**, and may be calculated from Ohm's law such as the following Equation (1).

$$I=V/R=V/(\rho*l/t) \tag{1}$$

"V" indicates a voltage between the cathode electrode **11** and the gate electrode **14**, and "l" indicates a length of a portion of the charging prevention film **13**, which connects the cathode electrode **11** and the gate electrode **14**. For example, the resistivity of the charging prevention film **13** may be in the range of about 10^7 ohms centimeter (Ω cm) to about 10^{10}Ω cm. The charging prevention film **13** may include a-Si, Cr_2O_3, TaN, RuO_2, PbO, NiCr, $Bi_2Ru_2O_7$ or the like.

Generally, electrons that are emitted from the electron emission sources **15** are discharged to the outside of the electron emission device **10** through the openings H of the gate electrode **14**. However, some of electrons that are emitted from the electron emission sources **15** may be incident on the charging prevention film **13**. Since the resistivity of the charging prevention film **13** is smaller than that of the gate spacers **12** and larger than that of the gate electrode **14**, electrons incident on the charging prevention film **13** move to the gate electrode **14** having a relatively high potential. Thus, charging of the gate spacers **12** with electric charges may be reduced or effectively prevented, and arcing may be reduced. In this manner, since the charging prevention film **13** is disposed between the electron emission sources **15** and the gate spacers **12**, charging of the gate spacers **12** with electric charges may be reduced or effectively prevented.

In manufacturing the electron emission device **10**, the gate electrode **14**, the gate spacers **12** and the charging prevention film **13** may be formed by deposition and patterning. In one embodiment, for example, a conductive material is deposited on a substrate to form the gate electrode **14**, and an insulation layer used in forming the gate spacers **12** is sequentially formed. Next, the gate spacers **12** are formed by patterning the insulation layer. Next, the gate electrode **14** may be formed by using a mask, after forming the charging prevention film **13** on the gate spacers **12** and an exposed portion of the cathode electrode **11** between the gate spacers **12**, to cover the gate spacers **12**.

In addition, electron emission sources **15** may be formed by directly forming metal, silicon, oxide, diamond, DLC, carbide compound, nitride, carbon nanotube, carbon nanofiber or the like on the cathode electrode **11**, such as by using a catalyst metal. Alternatively, the electron emission sources **15** may be formed by mixing a powder of a previously grown diamond, DLC, carbon nanotube, carbon nanofiber, or the like with paste together with a binder and then using screen printing or a photosensitive method.

The gate electrode **14**, the focusing gate **17** and the focusing spacer **16** may be formed by assembly, as opposed to using a deposition and/or patterning process, but the invention is not limited thereto or thereby. The electron emission device **10** may be manufactured by sequentially disposing and combining the gate electrode **14**, the focusing spacer **16** and the focusing gate **17** on a substrate including the cathode electrode **11**, the gate spacers **12**, the charging prevention film **13** and the electron emission sources **15** integrated thereon. In this manner, since assembly of the gate electrode **14**, the focusing gate **17** and the focusing spacer **16** is performed after individually manufacturing the cathode electrode **11**, the gate spacers **12** and the charging prevention film **13**, replacing a defective element becomes relatively easy if any one of elements of the electron emission device **10** is defective.

The charging prevention film **13** does not need to cover an entire of the gate spacers **12**. Although, in FIG. **1**, the charging prevention film **13** is disposed on all surfaces of the gate spacers **12** and on the exposed portion of the cathode electrode **11** between the gate spacers **12**, the present invention is not limited thereto. That is, the charging prevention film **13** may be disposed anywhere relative to the elements of the electron emission device **10** to reduce or effectively prevent electrons emitted from the electron emission sources **15** from colliding with the gate spacers **12**.

FIG. **3** is a cross-sectional view illustrating another embodiment of an electron emission device **20** according to the present invention. As illustrated in FIG. **3**, a charging prevention film **23** of the electron emission device **20** may be disposed at the lateral sides of gate spacers **12**. Since there is a high probability that electrons emitted from electron emission sources **15** collide with the lateral sides of the gate spacers **12**, the charging prevention film **23** may be disposed only at the lateral sides of the gate spacers **12** to minimize a leakage current of a gate electrode **14** and a cathode electrode **11**. The charging prevention film **23** may contact the gate electrode **14** so that electric charges of the charging prevention film **23** move to the gate electrode **14**. In an embodiment of manufacturing the electron emission device **20**, the charging prevention film **23** may be formed by using a photolithography process.

In addition, in order to minimize collisions between electrons emitted from the electron emission sources **15** and the charging prevention film **23**, the charging prevention film **23** and/or the gate spacers **12** may be disposed aslope (e.g., inclined) with respect to the electron emission sources **15**.

FIG. **4** is a cross-sectional view illustrating another embodiment of an electron emission device **30** according to the present invention. As illustrated in FIG. **4**, the cross-sectional width of each gate spacer **32** may be smaller in a direction from a cathode electrode **11** to a gate electrode **14**. Since the cross-sectional width of each gate spacer **32** decreases in the direction from the cathode electrode **11** to the gate electrode **14**, a charging prevention film **33** that is disposed on the surfaces of the gate spacers **32** is disposed aslope with respect to electron emission sources **15**. In the direction from a cathode electrode **11** to a gate electrode **14**, a distance between the charging prevention film **33** and the electron emission source **15** increases. Thus, a probability that electrons emitted from electron emission sources **15** collide with a charging prevention film **33** is lowered.

In addition, the electron emission device **30** may more effectively focus electrons by using a plurality of focusing gates as shown in FIG. **5**.

FIG. **5** is a cross-sectional view illustrating another embodiment of an electron emission device **40** according to the present invention. As illustrated in FIG. **5**, the electron emission device **40** may include two focusing gates **47** and **49** and two focusing spacers **46** and **48**. In one embodiment, for example, the electron emission device **40** may include a first focusing spacer **46**, a first focusing gate **47**, a second focusing spacer **48** and a second focusing gate **49**, which are sequentially disposed on the gate electrode **14**. If a positive voltage is applied to the first focusing gate **47** and a negative voltage is applied to the second focusing gate **49**, electrons emitted from electron emission sources **15** may be more effectively focused.

FIG. **6** is a diagram illustrating an embodiment of an X-ray generator **100** including an electron emission device **10**, according to the present invention.

Referring to FIG. **6**, the X-ray generator **100** includes a container unit **50**, the electron emission device **10** installed in the container unit **50**, and an anode **60** for converting electrons emitted from the electron emission device **10** into X-rays. A window **50***a* that may output the X-rays to the outside of the container unit **50** is disposed at one side of the container unit **50**. The electron emission devices **20**, **30** and **40** illustrated in FIGS. **3** through **5** as well as the electron emission device **10** illustrated in FIG. **1** may be applied to the X-ray generator **100** of FIG. **6**.

The shape of the container unit **50** is not limited to that of the illustrated embodiment. The container unit **50** may be shut tightly to maintain a vacuum state thereinside, and may further include an exhaust portion (not shown) connected to an external vacuum pump to exhaust internal gas to the outside of the container unit **50**. The container unit **50** may include a material that blocks X-rays, for example, steel use stainless ("SUS"), glass, or the like. When the container unit **50** includes glass, the container unit **50** may further include an X-ray shield material that additionally blocks the X-rays, and, for example, may further include Pb or a heavy metal material. The window **50***a* may include an X-ray transmission material to discharge the X-rays to the outside of the container unit **50** while maintaining a vacuum state of the inside of the container unit **50**, and, for example, may include Pyrex® glass, Al, or the like.

The electron emission device **10** may be the electron emission device **10** of FIG. **1**, and may be disposed on a fixing portion **10***a*. The fixing portion **10***a* on which the electron emission device **10** is installed may be detachable from and attachable to the container unit **50**.

The anode **60** generates an X-ray by using an electron beam generated from the electron emission device **10** and includes a target **62** including a metal such as Mo, Ag, W, Cr, Fe, Co, Cu, or the like or a metal alloy. The electron emission device **10** and the anode **60** may be connected to an external power supplier (not shown).

FIG. **7** is a diagram illustrating a result of an experiment regarding a relationship between an interval d_2 between the gate bridges **14***b* and an electrical current in microamps (μA) flowing through the anode **60**, according to the present invention. With the interval d_2 between the gate bridges **14***b* as twice the distance h between the electron emission sources **15** and the gate electrode **14**, an electrical current flowing through the anode **60** depending on a gate voltage in volts (V) was measured. In addition, with the interval d_2 between the gate bridges **14***b* as four times the distance h between the electron emission sources **15** and the gate electrode **14**, an electrical current flowing through the anode **60** depending on a gate voltage was measured.

As illustrated in FIG. **7**, when the same gate voltage is applied, an electrical current flowing through the anode **60** when the interval d_2 is twice the distance h (TWICE), is larger than that flowing through the anode **60** when the interval d_2 is four times the distance h (FOUR TIMES). This means that electron emission efficiency is higher when the interval d_2 is twice the distance h, compared to when the interval d_2 is four times the distance h.

One or more embodiment of the electron emission device according to the present invention may reduce or effectively prevent a loss thereof due to arcing since a film for preventing gate spacers from being electrically charged is disposed on the gate spacers. In addition, a uniform electric field may be formed since the gate electrode of the electron emission device has a mesh structure.

While the present invention has been particularly shown and described with reference to embodiments thereof, it will be understood by those of ordinary skill in the art that various changes in form and details may be made therein without departing from the spirit and scope of the present invention as defined by the following claims.

What is claimed is:

1. An electron emission device comprising:

a cathode electrode;

a gate electrode spaced apart from the cathode electrode, and a plurality of openings defined in the gate electrode;

a plurality of gate spacers spaced apart from the gate electrode, between the cathode electrode and the gate electrode; and

a plurality of electron emission sources between the cathode electrode and the gate electrode, and alternating with the plurality of gate spacers,

wherein

a first portion of each electron emission source is exposed by an opening among the plurality of openings defined in the gate electrode, and a second portion of each electron emission source is overlapped by the gate electrode.

2. The electron emission device of claim **1**, wherein the gate electrode comprises:

a plurality of gate lines respectively on the plurality of gate spacers; and

a plurality of gate bridges which connects the plurality of gate lines to each other.

3. The electron emission device of claim **2**, wherein an interval between two adjacent gate bridges from among the plurality of gate bridges is equal to or greater than a width of a gate bridge.

4. The electron emission device of claim **2**, wherein an interval between two adjacent gate bridges from among the plurality of gate bridges is equal to or less than twice a distance between the plurality of electron emission sources and the gate electrode.

5. The electron emission device of claim **1**, wherein each of the plurality of gate spacers or each of the plurality of electron emission sources is linear-shaped.

6. The electron emission device of claim **1**, further comprising a charging prevention film on the plurality of gate spacers, wherein the charging prevention film prevents electrical charging of the plurality of gate spacers by electrons emitted from the plurality of electron emission sources.

7. The electron emission device of claim **6**, wherein the charging prevention film is on lateral sides of the plurality of gate spacers and is connected to the gate electrode.

8. The electron emission device of claim **7**, wherein the charging prevention film is further on at least one of an upper side of each gate spacer and an upper side of a portion of the cathode electrode which is exposed between adjacent gate spacers.

9. The electron emission device of claim **6**, wherein a resistivity of the charging prevention film is between a resistivity of the gate electrode and a resistivity of the plurality of gate spacers.

10. The electron emission device of claim **6**, wherein a resistivity of the charging prevention film is in a range from about $10^7 \Omega$ cm to about $10^{10} \Omega$ cm.

11. The electron emission device of claim **1**, wherein a cross-sectional width of each gate spacer decreases in a direction from the cathode electrode to the gate electrode.

12. The electron emission device of claim **1**, further comprising:

a focusing gate spaced apart from the gate electrode, wherein the focusing gate focuses electrons emitted from the plurality of electron emission sources; and

a focusing spacer between the gate electrode and the focusing gate.

13. The electron emission device of claim **12**, further comprising:

a plurality of focusing gates comprising first and second focusing gates sequentially disposed and spaced apart from the gate electrode, and

a plurality of focusing spacers comprising first and second focusing spacers, wherein the first focusing gate is disposed between the first and second focusing spacers.

14. The electron emission device of claim **13**, wherein the first focusing gate is applied with a positive voltage and the second focusing gate is applied with a negative voltage.

15. The electron emission device of claim **1**, wherein the cathode electrode, the plurality of gate spacers and the plurality of electron emission sources are integrated, and the gate electrode is detachable from and attachable to the plurality of gate spacers.

16. An X-ray generator comprising:

a container unit;

the electron emission device of claim **1** in the container unit; and

an anode which generates X-rays by using electrons emitted from the plurality of electron emission devices.

17. The X-ray generator of claim **16**, wherein the electron emission device is detachable from and attachable to the container unit.

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